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Aerosolized Coal Fly Ash: A Previously Unrecognized Primary Factor in the Catastrophic Global Demise of Bird Populations and Species

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Objectives: Bird populations and species world-wide are experiencing die-offs on an unprecedented scale. Forensic evidence is consistent with coal fly ash (CFA), the toxic waste product of coal-burning, being the main aerosol particulate utilised in atmospheric geoengineering. The principal objective of this paper is to disclose previously unrecognised factors, arising from CFA, which underlie the catastrophic and global decline of birds.
Methods: We utilised inductively coupled plasma mass spectrometry (ICP-MS) and conducted extensive literature research.
Results: New data presented here confirm the unmistakable footprint of CFA in atmospheric precipitation and air-drop samples. Review of the literature reveals the increasing importance of air pollution on global bird populations. Aerosolized CFA, a particularly toxic form of air pollution, contains multiple metals and elements well-known to adversely affect all portions of the avian life cycle, in aerial, terrestrial, and marine environments. Studies from around the globe reveal systemic contamination of birds by these elements.

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Conclusions: Coal fly ash, including its use in ongoing atmospheric geoengineering operations, is a major factor in global bird die-off. The accelerating decline of birds parallels the catastrophic decline of insects, due in part to the same type of aerial pollution. There is an urgent need to recognise and halt atmospheric geoengineering if there is to be any chance of reducing the drastic decline of birds and the associated degradation of natural ecosystems. If the aerial spraying can be stopped, the gradual recovery of bird populations would be the best evidence that CFA is, in fact, a leading cause of the drastic avian decline.

Keywords: Bird population decline; bird species decline; bird diversity decline; global bird die-off; coal fly ash; geoengineering; global warming; climate change.

1. INTRODUCTION

Birds are showing precipitous declines in population numbers on a world-wide basis [1]. There are currently at least 1470 species of birds threatened with extinction, approximately one out of eight world-wide, which is an increase of 40% since the first global assessment of threatened species in 1988 [1]. Bird species have faced an especially steep increase in extinction risk in South-East Asia, in the Pacific Islands, in polar regions, and in marine and coastal ecosystems [2]. Of the 1200 waterbird populations with known trends, 44% are in decline [2]. The monitored portion of global seabird population declined by nearly 70% between 1950 and 2010 [3]. Even birds in tropical protected areas are showing declines up to 40-50% since 2008 [4]. Farmland birds in Europe have declined by an average of 50% since 1980 [5]. Across Africa, many raptors, including vultures, are in dramatic decline [6].

One-third of North American bird species are at risk of extinction in the near-term: Of the birds that are found in North America (Canada, Mexico, and the United States), 432 out of 1154 species are on the Watch List of high vulnerability [7]. Since 1967, the average population, of certain common birds with the steepest declines in North America, has fallen by up to 70% [8]. The abundance of birds recorded in the North American Breeding Bird Survey decreased by 18% between 1966 and 2005 [9]. Nesting (breeding) bird abundance decreased most consistently in species that either resided (19% of overall loss), or migrated within the U.S. and Canada (30% loss). Long distant migrants did not incur greater losses [9].

Industrial pollution, agricultural practices, loss of habitat, deforestation, logging, invasive species, intentional killing, and climate instability rank among the most important threats to birds on a world-wide basis [1,10]. Yet, the great rate of reduction in bird populations and species implies the existence of an overriding factor of global scale that has not been considered by the scientific community. Here we describe a major, previously unrecognised factor in global bird die-offs.

Many in the scientific community, including the politically-influential United Nations' Intergovernmental Panel on Climate Change (IPCC), have failed to acknowledge [11] the global-scale, tropospheric aerosol particulate-pollution geoengineering-activities that have taken place for decades, as illustrated by Fig. 1. Scientists operating within that paradigm have difficulty identifying the causes and then halting, the appalling reduction of avian populations and species.

The IPCC and a number of scientists ascribe to the proposition that greenhouse gases, notably anthropogenic carbon dioxide, cause global warming by trapping heat that should otherwise be radiated into space, and to the assumption that particulate matter sprayed into the troposphere will cool the Earth [12-14]. Presumably militaries of many countries engaged in near-daily, near-global atmospheric modification activities, including jet-spraying particulate matter into the region where clouds form [15]. Through the application of forensic scientific methodology, we have demonstrated that the main particulate substance sprayed into the atmosphere is consistent with coal fly ash, the toxic waste product of industrial coal-burning, that in some nations is considered too harmful to be allowed to exit smokestacks [16-18].

Our purpose here is to describe and present additional evidence pointing to coal fly ash being used in global, atmospheric manipulation activities [11,15-19], and to describe with specificity how these operations constitute a primary, unrecognised factor in the worldwide bird die-off.

Fig. 1. Photographs of tropospheric aerial particulate geoengineering trails. Rows top to bottom, left to right: 1) Calgary, Alberta (Canada), Courtesy of Dan Pelletier; Gold Hill, Oregon (USA), Courtesy of Billy Moon; 2) Geneva, Switzerland, Courtesy of Beatrice Wright; Ashdod, Israel, by author JMH; 3) Sacramento, California (USA), Courtesy of Deborah Whitman; Yosemite, California (USA), Courtesy of Ricardo Beas

We have presented evidence that jet-sprayed particulate-pollution in the region where clouds form poses serious adverse human health consequences, including but not limited to, chronic obstructive pulmonary disease (COPD) [20], lung cancer [21], and neurodegenerative disease [22]. Furthermore, we have disclosed previously unsuspected evidence that coal fly ash particulates sprayed into the atmosphere is a major factor in forest die-offs worldwide [23] and is a major factor in global insect die-offs [24].

The global decline in birds is often considered parallel to the catastrophic loss of insects in recent decades [25,26]. As we describe here, there is a commonality due to intentionally aerosolised and dispersed coal fly ash, not only through reducing avian food supplies but by causing debilitating conditions affecting bird populations [27].

2. METHODS

Absent public disclosure as to the nature of the substance(s) being sprayed, concerned citizens had post-spraying rainwater samples analysed by commercial laboratories [16]. Usually, only aluminium elemental analysis was requested, sometimes barium as well, and occasionally also strontium [16,28]. As laboratories typically report results as metals in units of micrograms per liter or equivalent, concerned citizens have often mistakenly assumed that metals are being sprayed into the atmosphere. But that is not what the laboratory results reveal [29]. Although one cannot rule out instances of metals being aerosolised in this geoengineering activity, the appearance of these three elements as soluble salts dissolved in rainwater suggested a different origin, namely, aqueous extracts from a toxic waste product, coal fly ash [30].

A hypothetical example may help to understand the process involved. Imagine if powdered tea leaves were jet-sprayed into the atmosphere. Upon encountering moisture, tannin and other chemicals would be extracted into the water, in the same manner as in making tea to drink; the subsequent rain would be tea, albeit very weak tea.

Coal fly ash forms in the hot gases above the burner in coal fired furnaces, principally in electricity-producing utilities [31]. In Western nations, because of its toxicity, coal fly ash is trapped and sequestered rather than being allowed to exit smokestacks [32]. The electrostatic trapping employed, however, is not 100% efficient, allowing CFA to be detected downwind of the facility [32,33]. Laboratory experiments have shown that as many as 38 elements can be partially extracted by water [29,34] from CFA, the major industrial waste product that forms in the size needed for aerosolisation [31].

We have shown [17,18,23] that at least eleven elements measured in rainwater and snow, expressed as ratios, have the same composition-range as the corresponding element-ratios from water-leach experiments made on samples of coal fly ash from Europe and the United States as illustrated in Fig. 2. This is the first line of forensic scientific evidence showing that the main, undisclosed particulate matter jet-sprayed into the atmosphere is consistent with coal fly ash [CFA].

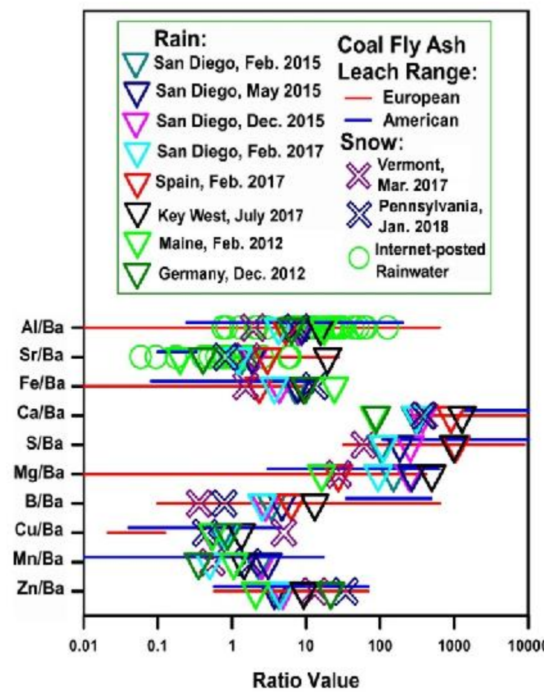

Fig. 2. From [23], showing the similarity of element ratios measured in rainwater and snow with the range of comparable element ratios measured in the laboratory lixiviate of water-leach experiments [29,34]

The soluble aluminum content is particularly disturbing due to its toxic nature to organisms [16,23,35]. Previously, aluminium in a chemically mobile form resulted from acid rain [36], but scrubbers for sulfur dioxide and nitrous oxides were added to trap these acid-producing oxides [37]. Now, the soluble aluminium problem has returned via aerosolised CFA. Our results on environmentally toxic elements extracted by atmospheric precipitation from aerosolised particulates, evidenced as CFA, are limited to the elements shown in Fig. 2 due to the sensitivity limitations of commercial laboratories. Hopefully, academic laboratories, many with greater sensitivity, will continue and extend this investigation.

Snowfall can bring down aerosolised particulate matter [17] in a manner similar to the co-precipitation techniques applied in analytical chemistry [38,39], dewatering [40], gold recovery [41], and in water treatment [42]. Initially, fresh snow was collected during a snowstorm on March 31, 2016 in Pearson, Wisconsin (USA), and allowed to melt, yielding initially 105 mL of liquid in a clean plastic container which was allowed to slowly evaporate. After most of the liquid had evaporated, the sample was diluted to 50 mL with 5% HNO3 solution, and vortexed to break the solids loose from the sides of the container. Next, the sample was digested per US EPA Method 200.7/6010b. After digestion, the sample was diluted to 52.5 mL and analysed by Inductively Coupled Plasma Mass Spectrometry (IPC-MS) by Northern Lake Service, Inc. Analytical Laboratory and Environmental Services in Crandon, Wisconsin (USA). The analytical results, expressed as ratios relative to barium, were compared with the range of similar element ratios measured in samples of European [29] and American [34] CFA samples [17].

Fig. 3. Snow mould observed and collected just after overlying snow had melted on April 21, 2014 in Didsbury, Alberta (Canada). Courtesy of Dan Pelletier.

Subsequently, that methodology was repeated with evaporated snow samples from 2017 [18] and 2018, reported here. In addition, the analytical procedure was repeated on samples of snow mould collected in Laona, Wisconsin (USA) on March 19, 2015 [18] and on a combined set of snow mould samples collected on April 21, 2014 in Didsbury, Alberta (Canada), Fig. 3, and reported here.

Coal fly ash contamination of the environment certainly occurs by other means in addition to CFA jet-spraying, as accidental-release evidence indicates [43]. On or about February 14, 2016, an oily-ashy substance fell on seven residences and vehicles in Harrison Township, Michigan, USA [43]. Analysis showed the airdrop material to be composed of plant material, coal fly ash, and salt that appeared (Fig. 4) to be a synthetic form of cryoconite that absorbs solar energy to melt itself into glacial ice [43].

In May 2018, a resident in Encinitas, California (USA) noticed unusual dust appearing on his car as he described in a statement: “What originally sparked my attention was the yellowish-green dust all over the entire hood, as I sat down in the driver seat and looked out of the windshield over the hood of my car. Then, as my eyes focused on the windshield, I could see the fine particles covering the entire windshield, as well. For numerous days, I would turn on the wipers and wash the windshield. Each day, it would be the same, as these particles would continuously return.”

Upon seeking advice from one of the authors (JMH), he collected a sample for analysis, and described the manner of collection, “I used a brand new, small hand broom and slowly (and lightly) swept this dust off the top of the cars. This included the hood, windshield, roof and sunroof, back window, trunk, and side windows. I carefully swept this dust into a plastic baggie,” (shown in Fig. 5).

The sample was then sent to Northern Lake Service, Inc. Analytical Laboratory for the same type of analysis as described above; the results are reported here.

The reason for dispersing the yellowish-green dust is a mystery, but certainly a matter of concern as the individual described in his statement: “I think it may be important to note that I had two incidences where I did not wear a mask or gloves and both times, within minutes of completing the collection, I experienced memory loss and confusion for at least 30 to 45 minutes.”

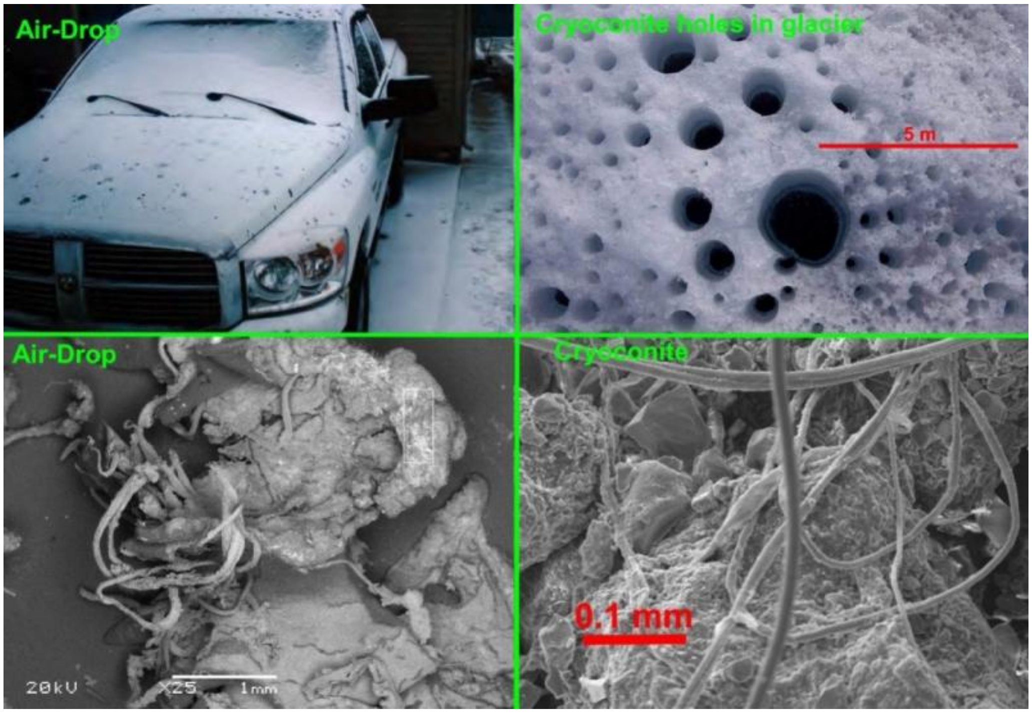

Fig. 4. Upper Left: Air-Drop distribution; Upper Right: Cryoconite-hole distribution in glacier; Lower (Scanning Electron Micrographs) Left: Air-Drop synthetic cryoconite; Lower Right: Natural cryoconite

Fig. 5. Yellowish-green dust recovered from cars in April 2018.

3. RESULTS AND DISCUSSION

Fig. 6 presents the new laboratory results, expressed as ratios relative to barium, for comparison with previous snow evaporation and snow mould analytical data. Some degree of natural variation in values is expected as indicated by the range in measured values of 23 European [29] and 12 American [34] CFA samples. There is, however, an internal overall consistency between diverse samples and between the ranges of the European and American CFA samples.

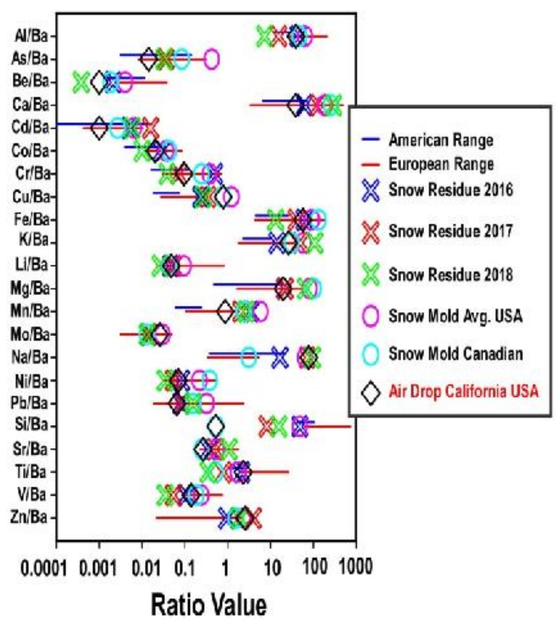

Fig. 6. Comparison of analytical results with the ranges of European [29] and American [34] CFA samples

Coal fly ash does not remain in the atmosphere but settles and contaminates the surface, hence the need for repeated aerial spraying [44]. Snow, we have shown [17], also brings down aerosolised CFA which upon melting drains down to contaminate matter beneath, such as snow mould [18], and soil. Many of the toxins in CFA are extracted by atmospheric moisture, becoming contaminated rainwater and fog-water [23], which also contaminates the environment. Previously, an accidental airdrop of different material, ascertained to contain CFA and plant matter, provided evidence of CFA contamination of the environment for the purpose of melting ice sheets [43]. The latest discovery of yellowish green air drop material (Fig. 5), reported here, evidence yet another means of CFA environment-contamination. There may be additional yet-unknown operations utilising CFA, posing environmental contamination, in addition to the direct release of CFA by coal-burning electric-utilities, from spills of sequestered CFA, and from unsafe CFA dumping practices [45].

3.1 Adverse Consequences of Coal Fly Ash on Bird Populations

We have begun to address aerosolised CFA risks to human populations [16,20-22], to insects including bees [24], and to trees and other plants [23,46]. We now discuss the specific adverse consequences of CFA on bird populations.

3.1.1 Consequences of anthropogenic global warming on avian decline

The near-daily, near-global jet-spraying of particulate matter, evidenced as mainly CFA, into the troposphere has major consequences on climate [47]. One consequence of aerosolised CFA is to exacerbate global warming [15,48], which evidence indicates is mainly caused by pollution, especially particulate pollution, not by greenhouse gases [19].

Climate instability ranks among the most important threats to birds on a world-wide basis [1]. Rapid climate warming is a global threat to biodiversity; there are significant declines in mammals and birds with rising temperatures, an effect which is more pronounced in birds [49]. The distributions of North American birds show clear evidence of latitudinal and elevation shifts, implicating changes in temperature, precipitation, and other climate/weather factors [50]. These altered climate factors cause mismatches in food supply, vegetation, nesting sites, migration timing, etc. that can severely impact fitness and reproduction [51]. Rapid changes in environmental conditions are likely to exceed the ability of many bird species to adapt, especially those with specialised habitat requirements [52].

Although some birds expanded their range with rapid global warming, emerging evidence suggests that climate-driven extinctions and range retractions are already widespread and underway [53]. Climate change is implicated in the dramatic retraction of range in the once-common Rusty Blackbird (*Euphagus carolinus*) [54]. Birds have limited abilities to adapt to rapid environmental changes. Habitat specialisation is a labile ecological trait, which may change in the short term following habitat degradation and generalist birds fare better than more specialised birds [55]. Foraging habits, prey items, habitat type, reproductive rate, and behavioural flexibility are factors in a bird's survival [56]. Insectivorous and carnivorous birds are at increased risk vs. herbivorous/omnivorous birds [56]. Air pollution affects all wild birds, it is cumulative over time, and it almost certainly reaches a threshold where population density and diversity are adversely affected [27].

3.1.2 Consequences of global, catastrophic insect demise on avian decline

The dramatic worldwide decline in insect populations and diversity is well documented [25,57-61]. Aerosolised coal fly ash (CFA), the toxic by-product of coal combustion, is a major contributor to this insect die-off [24] and, concomitantly, in the global decline of bird populations and diversity.

The catastrophic loss of birds in recent decades parallels the global decline of insects in recent decades [25,26]. Most passerine birds depend on insects for food, especially during the breeding season, and declining insect biomass adversely affects the weight, fitness, and survival of birds, including their nestlings [62]. North American populations of aerial insectivorous birds (e.g. swallows, swifts, nightjars, and flycatchers) are in steep decline [63]. These declines began in the 1980's with evidence of a response to a common environmental factor(s) with similar effects on many species across a wide area [63]. The probability of decline of aerial insectivores is related to migration distance, latitude, and longitude [64]. Declining body mass in swallows may result from carry-over effects from non-breeding areas and affect population dynamics by reduced survival [65]. Stable isotope studies of museum specimens (100 year period) are consistent with the hypothesis that aerial insectivore birds are declining due to changes in the abundance of their higher trophic-level prey [66].

3.1.3 Consequences of pollution on avian decline

Environmental pollution affects birds directly by contributing to mortality and reduced reproductive success [27]. Some of the most important sources of this pollution are from agriculture, forestry and industry. [10]. More than 60% of threatened waterbirds are affected by pollution. Heavy metals and persistent organic pollutants accumulate in waterbirds by direct contact and ingestion, resulting in decreased fitness and reproduction [67]. Heavy use of agrichemicals and pesticides cause the decline of both invertebrate and small vertebrate prey items for birds [25]. Pollution affects bird populations indirectly by changes in their habitats [68]. Such factors as canopy height, basal stand area, foliage cover, and biomass of invertebrates decrease as pollution increases [68]. Atmospheric pollutants including mercury are distributed globally and already accumulate in polar birds with deleterious effects [69]. Historical records indicate that the majority of mercury adversely affecting birds in the Florida Everglades was deposited over the past 40-50 years [70].

3.1.4 Consequences of global coal fly ash pollution on avian decline

When coal is burned, primarily by electric utilities, the heavy ash settles, while coal fly ash (CFA), the light ash, forms in the gases above the burner and would exit smokestacks, if not trapped and sequestered by modern regulations [45]. Coal fly ash is one of the world's most abundant waste products, and its disposal is problematic [71]. Often, it is simply dumped into surface impoundments or placed into landfills which threaten groundwater contamination and environmental pollution [72,73]. In many countries, including the U.S., a significant percentage of CFA is recycled into structural fill and such products as concrete [74]. Coal fly ash is also utilized in soil additives and fertiliser [75]. The main elements in CFA are oxides of silicon, aluminium, iron and calcium, with lesser amounts of magnesium, sulfur, sodium, chlorine, and potassium [29]. The many trace elements in CFA include arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), phosphorus (P), selenium (Se), strontium (Sr), thallium (Tl), titanium (Ti), vanadium (V), and zinc (Zn) [29]. Small amounts of polycyclic aromatic hydrocarbons and even radioactive nuclides are found in CFA [76,77].

Coal fly ash from coal-fired power plants is one of the main sources of anthropogenic particulate pollution on a world-wide basis [78]. Tropospheric aerosol geoengineering (TAG), increasing in scope and intensity in recent years, represents a hazardous form of CFA/PM pollution that contaminates air, water, and soil

[15,18,23]. This type of air pollution not only affects birds directly by respiration, but indirectly by triggering habitat degradation, increasing parasites, and reducing food sources like insects [79]. Pollution affects birds by means of both bottom-up (resource/nutrients) and top-down (predator-driven) mechanisms [80]. While most experimental studies examine the toxic effects of single pollutants, aerosolised CFA pollution potentially exposes birds to multiple agents, some of which accumulate over the lifetime of the bird [27]. Just a few of the world's 10,000 species of birds have been used to study the avian response to air pollution, and the animals used in laboratory studies may not be representative of the wild bird species most at risk from air pollution [27].

Chemical elements of coal fly ash (CFA) are found in significantly elevated amounts in wild birds (starling, owl, crow, and pigeon) exposed to an air-polluted environment [81]. The aluminum (Al), chlorine (Cl), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), silicon (Si), and vanadium (V) found in the skin, muscle, lungs, liver, and kidney of these birds were associated with histopathological changes. The lungs of the starling, owl, and pigeon were "severely" contaminated with Al, Fe, K, Mn and Si producing pulmonary congestion, pneumonitis, and mineral deposits [81]. Liver samples had increased amounts of Cl, Fe, Mg, Mn, and V; kidney with increased Cl and Fe, and both organs with degenerative/necrotic changes [81]. These findings implicate toxic effects of the primary components of CFA, e.g. Al, Fe, and Cl, not only in the avian lung, but these and other elements of CFA deposited into internal organs. Some of these same elements are likely to cause the external contamination of bird species as well. For Al, cobalt (Co), nickel (Ni), lead (Pb), and zinc (Zn), there are strong indications that external contamination has an important impact on the levels of these elements detected in feathers of certain birds of prey [82].

Aluminum (Al) and iron (Fe) are two of the primary potentially toxic elements in CFA [76]. Chemically mobile Al, formed by acid rain, was found to be associated with impaired avian reproduction [83]. Although acid rain has to a large extent been minimised by sequestering sulfur dioxide and nitrous oxides from coal-burning exhaust gases, chemically mobile aluminium is now commonly and widely produced by aqueous extraction from aerosolized CFA [16,23]. In birds, aluminium frequently affects eggshells and the metabolism of calcium and phosphorus, causing decreased calcium absorption and increased metabolic rate of its byproducts, resulting in aluminium incorporation into bone [84]. As in other organisms, birds must balance opposing properties of ionic iron, that of essential nutrient and a transition metal known for destructive oxidative reactions in excess [85]. Chronic ingestion of absorbable iron in the diet can lead to iron storage disease with a build-up of iron in the liver and other organs [86]. Iron storage disease is common in cage birds, but a wide variety of wild-caught birds have shown elevated hepatic iron content with resultant fibrosis and regenerative nodules [87].

There is growing evidence that environmental pollutants including heavy metals (Cd, Pb, As, Cu), persistent organic pollutants, and certain insecticides (e.g. DDT) disrupt iron homeostasis leading to systemic disease in humans and other animals [88].

Birds are of great importance as bioindicators of environmental contamination, including most of the toxic elements found in CFA [89]. Avian feathers are an effective non-destructive bio-monitoring tool of trace metal signatures, which can be obtained from either living birds or museum specimens [89]. Like the proverbial "canary in the coal mine," birds can be used to warn us of a coming ecological crisis [90], in the case of CFA pollution, a crisis already at hand [15]. The gross contamination of much of the remaining global insect population by components of aerosolised CFA will greatly magnify the concentration of these same elements in birds [24]. Some heavy metals are essential elements for organisms, but become toxic at high levels, affecting productive function and behaviour [91]. Heavy metals accumulate and are biomagnified through the food chain in avian species [91]. Elements including arsenic, cadmium, mercury and lead have no useful function in living organisms and may be toxic at any dose [92].

Heavy metals are usually higher in feathers than other bird tissues, and thus easier to detect and quantify [93]. Eleven trace elements (Mg, Al, Mn, Cu, Zn, Rb, Mo, Cd, Ba, Hg, and Pb) were detected in pigeon and raven feathers by ICPMS [93]. In general, higher levels of these elements were found in industrial habitats, but detectable levels were also found in urban and rural areas [93]. In studies of cattle egret, *Bubulcus ibis* L, in

Pakistan, high levels of Cu, Cd, Co, Pb, Ni, and Zn were associated with anthropogenic activities [94]. Elevated levels of Cd, Hg, and Pb in blood of Griffin vultures (*Gyps fulvus*) are associated with biomarkers of oxidative stress and damage to proteins, lipids and DNA [95]. Alarming concentrations of heavy metals (Cd, Zn, Ni, Pb, Cu, As) were found in feather samples of raptors from three different bird families in Pakistan [96]. Marked elevations of aluminum (to over 200 ug/g), iron (to 165 ug/g), as well as Cr, Mn, Ni, Cu, Zn, As, Se, Cd, and Pb were found in the feathers of Gentoo, chinstrap, and Adelie penguins in Antarctica [97]. These findings, similar to those in other parts of the world, clearly implicate contamination from human activities, especially the pollutants found in coal fly ash, which evidence indicates is consistent with troposphere atmospheric modification activities [11,18,19].

3.1.5 Consequences of mercury contamination on avian decline

Among elements in CFA, mercury (Hg) deserves special attention as it is a persistent, bio-accumulating, globally cycling element that severely affects nearly all living creatures [98]. For humans mercury environment-contamination is a matter of global public health concern [98]. Mercury bio-accumulates in the food chain and is known to be one of the most toxic elements/substances on Earth [99].

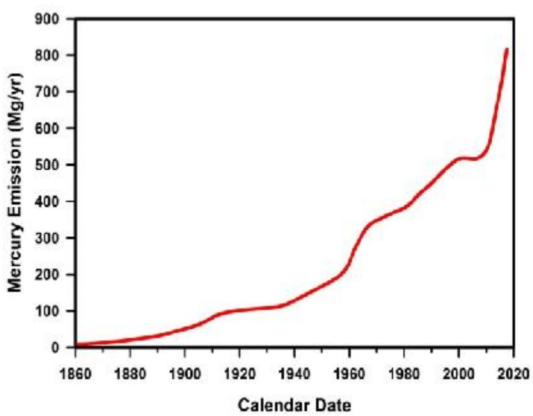

Fig. 7. Mercury emissions to the atmosphere from coal burning

Coal burning and geoengineering operations employing CFA have produced logarithmic increases in mercury throughout the biosphere in recent decades [18,100]. Fig. 7, constructed from the data of [101,102], provides annual estimates of mercury emissions from coal-burning operations, which represent approximately half of the total anthropogenic mercury emissions to the atmosphere [102]. The mercury emissions to the atmosphere from undisclosed CFA aerosolisation for geoengineering are unknown [18], but considering the global scale, may be substantial.

Bio-accumulation of methyl mercury (MeHg) has major adverse consequences on wildlife, and is most evident in apex predators, including birds [103]. Overall, 72% of field studies and 91% of laboratory studies found evidence of harmful effects of Hg on birds [103]. Strong evidence exists in the literature that mercury exposure in birds reduces reproductive output, compromises immune function, and causes avoidance of high energy behaviours [103]. A recent synthesis revealed 66% (2/3) of birds sampled in western North America exceeded a blood-equivalent Hg content of 0.2 ug/g wet weight (ww; above background levels), 28% exceeded 1.0 ug/g ww (moderate risk), 8% exceeded 3.0ug/g ww (high risk), and 4% exceeded 4.0 ug/g ww (severe risk) [104]. Ivory gulls (*Pagophila eburnea*), which consume ice-associated prey and scavenge marine carcasses, have declined over 80% since the 1980's in the Canadian Arctic [105]. The concentration of MeHg in Ivory Gull feathers from museum specimens from 1877 to 2007 increased 45 times (from 0.09 to 4.11ug/g) [105].

3.1.6 Consequences of ultrafine particulate matter on avian decline

Tracking black carbon deposits on bird specimens from the U.S. manufacturing belt between 1880 and 2015 showed that black carbon levels were correlated with coal consumption through the middle of the 20th century, after which black carbon on specimen birds declined even as coal consumption continued to rise [106]. This drop in atmospheric black carbon reflected policies promoting burning efficiency and fuel transitions rather than regulating emissions alone [106]. The relative amount of ultrafine particulate matter and nanoparticles in CFA is higher than any other combustion-derived material, falling in the range of $PM_{2.5}$ down to $PM_{0.1}$ [107,108]. Ultrafine particles in coal fly ash often escape filtering devices like electrostatic precipitators [109]. These ultrafine particles persist in the atmosphere longer and are more useful in the

CFA aerosols employed in climate alteration. However, ultrafine particles are also among the most toxic particles based on their greater number, a larger content of redox active compounds, greater surface to mass ratio, and ability to penetrate cell walls [110]. This type of pollution poses a greater respiratory risk; birds are now more likely to be "coated" with the type of tiny particles rich in iron and aluminosilicates similar to those detected adhering to the body of the honey bees [111].

Most airborne pollution particles in the $PM_{2.5}$ range and smaller are very reactive agents [112]. High intake of these particles causes oxidative stress by increasing the formation of reactive oxygen species (ROS), thereby rendering antioxidants incapable of defence against growing amounts of free radicals [112]. Birds have a faster metabolic rate than that of humans, which is likely to affect both particle uptake and detoxification [113]. Iron and Cu increase ROS directly through redox cycling [114], and redox-inactive metals (Pb, Cd, and Hg) increase ROS by uncoupling oxidative phosphorylation in the mitochondria or by depleting cellular anti-oxidants [115]. Bird density, biomass, and biodiversity decrease with increased proximity and level of exposure to the sources of heavy metal pollution [116]. This loss of birdlife may not occur in a strictly dose-dependent manner to individual pollutants, but rather reflects the combined effect of multiple pollutants on birds, and the effect of these pollutants on their breeding resources, such as food and suitable habitat [116].

3.1.7 Consequences of aquatic contamination on avian decline

The intentional or accidental release of coal combustion residues (CCR), the majority being coal fly ash, into aquatic systems is associated with deleterious environmental effects [117,118]. CCR exposure leads to histopathological, behavioural, and physiological effects in a wide variety of vertebrates and invertebrates [117,118]. Fish, amphibians, reptiles, mammals and birds accumulate CCR contaminants as a result of their feeding niche/trophic status over time [117]. Excessive levels of selenium are toxic and associated with fish extirpation events [119]. Elevated levels of copper, zinc, iron, manganese, lead, cobalt, and cadmium have been detected in water and aquatic insect samples from polluted sites [120]. These and other metals leached from coal fly ash are associated with oxidative stress [120]. Insectivorous birds are at increased risk from exposure to high levels of selenium, arsenic, and strontium [121]. There is an increased Hazard Quotient (HQ) to birds from dietary intake of Al and Fe in this setting [121]. Common grackle nestlings associated with coal fly ash basins accumulate Se, As, Cd, and Sr via dietary exposure [122].

3.1.8 Consequences of maternal transfer on avian decline

Maternal transfer is a significant source of exposure of bio-accumulative pollutants in birds [123]. Tree swallows (*Tachycineta bicolour*) breeding in CFA-contaminated sites concentrates key elements of CFA (Ba, Se, Sr, and Tl) in their eggs [123]. Among 26 constituents of CFA examined, Se, Sr, Cu and Hg were elevated in tissues of tree swallows and Se, Sr, and Cu were associated with decreased egg weight and net productivity [124]. Strontium (Sr), in particular, accumulates in eggshells and is correlated with impaired reproduction [125]. Aluminium was found in the bone marrow of wild pied flycatchers (*Ficedula hypoleuca*), and also linked to defective eggshell development [126]. Concentrations of 18 trace elements in grey heron (*Ardea cinerea*) eggshells from Poland followed the order: Si>Sr>B>Al>Zn>Fe>Ba>Li>Cu>Mn>Se>As>Cr>Ni>Pb>Sc>V>Cd [127]. Concentrations of inorganic elements in passerine birds from Arizona showed that Al, Ba, Cr, Cu, Mn, Se, Sr, and Zn were present in egg contents of all species, while As, Ni, Pb, and V were detected primarily in eggshells [128]. Arsenic is the most teratogenic and carcinogenic of these elements [129]. Aluminum, Cd, Hg, and Pb are associated with decreased hatchability and increased hatching mortality [130].

3.2 House Sparrows as a Microcosm of Avian Decline

The House Sparrow (*Passer domesticus*) has been successfully introduced throughout the world and is one of the most broadly distributed vertebrate species [131]. House sparrows are highly adaptable and closely associated with human habitation, ranging from countryside to large cities. These birds live alongside people everywhere – they are a generalist, granivorous, gregarious, and relatively sedentary [131]. They are unbothered by humans and able to exploit new food sources. It is therefore very surprising that in recent decades populations of house sparrows have dropped precipitously (up to 50-60%) in many areas including highly developed regions of Western Europe [132]. There is no consensus for this decline, but air pollution has been highlighted as one of the main driving factors [133]. Changes in markers of oxidative stress (e.g., haemoglobin/total antioxidant capacity) and linked to pollution have been documented in house sparrows, an effect more prominent in urban vs. rural birds [133].

House sparrows declined in Finland approximately 70% in urban and 65% in rural areas from 1987-2009 [134]. Heavy metals found in liver tissue from of house sparrows from both urban and rural areas from Finland include Al, Fe, Mn, Cu, Zn, Cd, and Pb [134]. Concentrations of Cu, Cd, Pb and Zn were measured in different tissues and organs of male and female house sparrows from the West Bank [135]. Tissues and organs with highest concentrations of these elements were in order: liver > stomach > bone > lung > feathers > muscles > egg contents > brain > heart > egg shell. Adult sparrows from rural areas were found to have less Cu, Pb, and Zn – but not Cd, than urban birds [135]. These and other studies reveal systemic contamination of these common birds by primary and trace elements found in aerosolised coal fly ash [76]. The studies indicate that house sparrows are effective bio-monitors of atmospheric pollution and suggest that their contamination with heavy metals (and resulting oxidative stress) may be one of the main reasons for their disappearance [133]. Although house sparrows eat grains, seeds, and vegetable material, their nestlings still depend heavily on insect food [136] so the catastrophic loss of insects is probably also an important factor in their decline. The continued global loss of this well-adapted urban bird demands further investigation and preventive action [134].

3.2 Adverse Effects of Declining Bird Populations on Ecosystems

The accelerating decline and extinction of bird species threaten to disrupt vital ecosystems [137]. Birds play an essential role in ecosystems as predators, pollinators, scavengers, seed dispersers, and decomposers [137]. A meta-analysis indicates that plants benefit from the presence of birds, in terms of both increased biomass and decreased disease [138]. The loss of apex consumers like birds has cascading effects of their disappearance from marine, terrestrial, and freshwater ecosystems world-wide [139]. Conservation biology tends to be a crisis-oriented discipline focused on simply maintaining minimal viable populations in remaining critical habitat, and healthy ecosystems are often appreciated only after their loss [140]. Drastic avian declines may actually be a best case scenario because many fish, amphibian, reptile, and mammal populations are even more threatened [141]. The effects of human activities, including air pollution, on defaunation, have arisen chiefly in recent decades [141]. As K. H. Redford concludes in his landmark article on anthropogenic destruction of wildlife (including birds) in ecosystems, “An empty forest is a doomed forest” [142].

Table 1 summarizes the some of the adverse effects of the components of coal fly ash on birds.

3.3 Proposal for Further Research

Quoted in an article in the October 18, 2018 issue of *The Guardian*, Dr. Tedros Adhanom Ghebreyesus, Director-General of the World Health Organization, warned of the dangers of air pollution, saying the simple act of breathing is killing 7 million people a year and harming billions more. Without mentioning the near-global, near-daily geoengineered pollution of our atmosphere, the article quite precisely asserts: *“No one, rich or poor, can escape air pollution. It is a silent public health emergency. Despite this epidemic of needless, preventable deaths and disability, a smog of complacency pervades the planet. This is a defining moment and we must scale up action to urgently respond to this challenge.”*

The *“smog of complacency pervades the planet”* with respect to air pollution’s effect on birds as well. It is especially important to quantify the adverse effects of CFA on bird populations as this is one type of air pollution that can be reduced and, in the case of tropospheric geoengineering, can be halted entirely.

Table 1. A summary of some of the adverse effects of the components of CFA on birds

Major Elements
Aluminum – has no biological function – chemically mobile form produced by aqueous extraction from aerosolized CFA – impairs reproduction – affects eggshells by interactions with calcium and phosphorus – Al incorporates into bones – Al found in feathers, lungs, skin, muscle, liver and kidney (with associated histopathological changes) in birds from polluted areas. Al is implicated in external contamination of birds from air pollution.
Silicon – is associated with Al as aluminosilicates – a primary component of CFA – and a desiccant – high levels found in lungs and eggshells, but often found in skin and internal organs of birds (when included for testing) in polluted environments.
Iron – is essential nutrient but toxic in excess and associated with destructive oxidative reactions. Fe is a highly reactive atmospheric pollutant that produces lung inflammation and disease. Fe builds up in liver and leads to degenerative/necrotic changes in this organ. Chronic ingestion of iron is associated with iron storage disease. Heavy metals (Cd, Pb, As, and Cu), persistent organic pollutants, and some insecticides (e.g. DDT) potentially cause systemic disease by impairing iron homeostasis.
Minor and Trace Elements
Mercury – is a persistent, bio-accumulating, and globally cycling element that affects all nearly all living creatures. Methyl mercury (MeHg) accumulates in the food chain with toxicity most evident in apex predators including birds. There is strong evidence that Hg exposure in birds reduces reproduction and compromises immune function. There has been a steady increase in levels of mercury in certain birds suffering staggering population loss in recent decades.
Selenium – is toxic in excess – accumulates in food chain – it is associated with fish kills, it is toxic to birds especially in aquatic environments – there is increased risk of selenium in insectivores (including documentation from CFA basin environments).
Strontium – accumulates in eggshells and is correlated with impaired avian reproduction.
Lead, Cadmium, Chromium, and Arsenic – all can be found in certain tissues of birds and associated with pollution. All these elements are associated with increased oxidative stress. Cd and Hg, along with Hg and Al are associated with decreased hatchability and increase hatching mortality. Pb, Cd, and Hg have no useful function in living organisms and can be toxic at any dose.
Important Principles – The majority of these toxic elements gradually accumulate over the lifetime of the bird. Birds have a limited ability to excrete elements like heavy metals (although there is some excretion in urine/feces, and feathers during molt). There is to date little understanding of the combined/interactive effects of these elements, since most of the experimental studies focus on single pollutants.

The alarming and unprecedented loss of birds, insects, and other wildlife has greatly accelerated since the turn of the century [4,25] and it corresponds to the rapid global expansion of atmospheric geoengineering during this time [15]. Previously published and new data here reveal the clear footprint of CFA in precipitation and air-drop samples from North America and Europe, including sites far removed from coal-fired power plants. We urge others to replicate and expand these findings. Additionally, $PM_{2.5}$ and ultra-fine pollution particles in ambient air and surface water samples from areas around the world should be specifically analyzed for both the primary chemical components, e.g. iron oxides in the typical spherical morphologies characteristic of CFA. Similar analyses should be conducted for the toxic trace elements found in CFA. These same elements can be quantified in feathers and tissue ranging from museum specimens to the wild (including dead and dying) birds of today, giving us a historical record of accumulating CFA-type pollution and its correlation with avian die-off [105]. Much more study is needed to better understand the many pathological effects of the particulate matter in aerosolized CFA on birds and other living creatures. Involvement in these studies may help to dispel the "*smog of complacency*."

4. CONCLUSIONS

Placing aerosolized coal fly ash (CFA), with its high concentration of toxic elements, into the troposphere profoundly and adversely affects human and environmental health in numerous ways as described here and in previous publications [11,15,16,18,20-24,46,118,143].

There may indeed be additional adverse consequences that have not yet been foreseen or envisioned, including consequences that may manifest only after decades following exposure as with some cancers [20-22]. The scientific community has ignored the aerial spraying and has failed to disclose the full truth [11] and in doing so has infected science with the ethics of politics.

Science is all about finding out what is wrong with extant ideas [30], but, in our opinion, the geoscience community has abandoned that ethos in favor of consensus conformity. Since 1989, the UN's Intergovernmental Panel on Climate Change (IPCC) has promoted the idea that anthropogenic carbon dioxide is the prime driver of global warming and has advocated 'future' geoengineering as a means to compensate [144]. The near-daily, near-global aerial particulate spraying in the troposphere is presumably undertaken to reduce global warming under the aegis of some publically-undisclosed international agreement(s) [15].

The progression of science is one of continuously correcting mistakes and misunderstandings [145]. The climate science community, including the IPCC, has made a very big and costly mistake: Air pollution, especially particulate pollution, is, as evidence suggests, the principal cause of global warming [19]. Spraying particulates into the troposphere to reduce global warming is like dousing a fire with gasoline to extinguish it [19].

Life on Earth exists in highly complex and complicated interrelated interactions among diverse biota and their physical and chemical environments. In 1962, Rachel Carson, in her book *Silent Spring*, called attention to the pervasive and senseless damage to the environment and to Earth's creatures caused by reckless, widespread use of pesticides. *Silent Spring* [146] gave birth to the modern environmental movement. The environmental organizations that stemmed from that movement, however, are seemingly unaware of the new threat to virtually all life, including humans, posed by the widespread and pervasive tropospheric spraying of coal fly ash. That threat is potentially much more devastating than the pesticide threat Rachel Carson addressed, as it can potentially render Earth incapable of supporting life.

Coal fly ash used in tropospheric geoengineering heats the atmosphere, causes global warming, glacier melting, and climate chaos [47]. It can be used to change weather/climate and/or to deliberately cripple an agricultural economy and inflict hardship and suffering [15,46]. Coal fly ash tropospheric geoengineering disrupts habitats for virtually all creatures, including arable habitats humans rely on for food crops [18,23,24]. The aluminum that water extracts from CFA in a chemically mobile form poisons the soil and kills plants and trees [23,35]. Long periods of geoengineering-caused drought can wreak economic disaster on farmers, and can shift the delicate balance in nature, weakening natural defences and giving a boost to aggressive pathogens, such as extreme-tolerant fungi [15,23,46].

We have published evidence that CFA geoengineering is a heretofore unrecognised primary factor in the demise of forests [23] and insects, including bees [24] and poses severe public health risk factors for humans [20-22]. Here we have presented evidence that aerosolized CFA is a major factor in the demise of birds.

Over 55 years have passed since Rachel Carson's *Silent Spring* exposed the devastating effects of DDT on humans, birds, and other living creatures. It is impossible to ignore the multiple threats to birds from anthropogenic causes and a burgeoning human population. However, the current accelerated global die-off of birds implicates high-intensity global ecological stressors that are disastrously harmful to all birds. Already there is growing concern for both air pollution and climate change as such primary factors in the wholesale loss of birds across diverse lineages and geographical areas. Coal fly ash (CFA) is an acknowledged global source of industrial pollution that contaminates air, water, and soil, but there is an unacknowledged and potentially more devastating global source of CFA pollution: Previously published data, updated in this study, are consistent with CFA being the main unidentified particulate aerosol used in secret, undisclosed tropospheric geoengineering. Coal fly ash, including its use in current geoengineering operations across the globe, represents a dire, but yet largely unrecognised and neglected cause of avian die-off. CFA-type pollution affects birds in aerial, terrestrial, and aquatic environments. Birds from sites around the world display evidence of systemic contamination with the primary elements and multiple toxic trace elements found in CFA. The global decline of birds parallels the catastrophic die-off of insects, which show the same type of severe contamination by CFA [24]. Coal fly ash is a cause of avian mortality that can be reduced by halting atmospheric geo-engineering and further controlling industrial emissions. However, the "deafening silence" on the subject of this type of CFA pollution must be broken if we are to have any chance of slowing our rapid descent into ecological disaster.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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